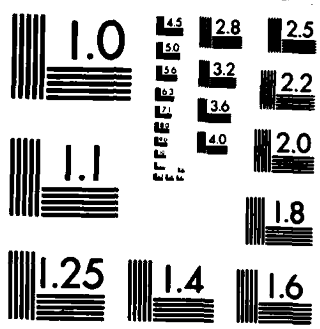
AD-A151 810 DEFAULT SHIP CHARACTERISTICS FOR SALVAGE CALCULATIONS 1/1
(U) WASHINGTON CONSULTING GROUP DC C R THOMPSON ET AL.
NOV 84 USCG-D-35-84 DTCG23-83-C-20065

UNCLASSIFIED F/G 13/10 NL

END
FILMED
DTIC




MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

@ (2)

AD-A151 810

Report No. CG-D-35-84

# DEFAULT SHIP CHARACTERISTICS
# FOR SALVAGE CALCULATIONS

C. R. Thompson
L. Reinberg

FINAL REPORT
November 1984



Prepared for:

U.S. Department of Transportation
United States Coast Guard

Office of Research and Development
Washington, D.C. 20593

**Technical Report Documentation Page**

1. Report No.: CG-D-35-84
2. Government Accession No.: AD-A151810
3. Recipient's Catalog No.:
4. Title and Subtitle: Default Ship Characteristics for Salvage Calculations
5. Report Date: November 1984
6. Performing Organization Code:
7. Author(s): C. R. Thompson and L. Reinberg
8. Performing Organization Report No.:
9. Performing Organization Name and Address:
   The Washington Consulting Group
   1625 Eye Street, N. W.
   Suite 214
   Washington, D. C. 20006
10. Work Unit No. (TRAIS):
11. Contract or Grant No.: DTCG 23-83-C-20065
12. Sponsoring Agency Name and Address:
    Commandant (G-DMT-3)
    U. S. Coast Guard
    2100 Second Street, S. W.
    Washington, D. C. 20593
13. Type of Report and Period Covered: Final Report
14. Sponsoring Agency Code:
15. Supplementary Notes:
16. Abstract

This study confirms that default data calculations can be used to develop ship hydrostatics, and strength information of suitable accuracy to allow the Coast Guard On-Scene Coordinator (OSC) to make rapid and intelligent judgments of ship grounding incidents. The study recommends the calculations be performed on a small portable computer, which would be carried to the emergency site by the OSC and would be fitted with graphic read-out capability for displaying numbers and simple sketches.

17. Key Words:
    Salvage
    Ship groundings
    Default characteristics
18. Distribution Statement: Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.
19. Security Classif. (of this report): Unclassified
20. Security Classif. (of this page): Unclassified
21. No. of Pages: 66
22. Price:

Form DOT F 1700.7 (8-72)

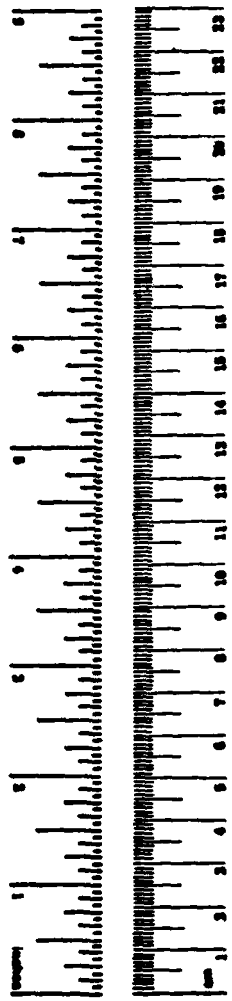
Reproduction of completed page authorized

## METRIC CONVERSION FACTORS

### Approximate Conversions to Metric Measures

| Symbol | When You Know | Multiply by | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| in | inches | *2.5 | centimeters | cm |
| ft | feet | 30 | centimeters | cm |
| yd | yards | 0.9 | meters | m |
| mi | miles | 1.6 | kilometers | km |
| | | **AREA** | | |
| $in^2$ | square inches | 6.5 | square centimeters | $cm^2$ |
| $ft^2$ | square feet | 0.09 | square meters | $m^2$ |
| $yd^2$ | square yards | 0.8 | square meters | $m^2$ |
| $mi^2$ | square miles | 2.6 | square kilometers | $km^2$ |
| | acres | 0.4 | hectares | ha |
| | | **MASS (weight)** | | |
| oz | ounces | 28 | grams | g |
| lb | pounds | 0.45 | kilograms | kg |
| | short tons (2000 lb) | 0.9 | tonnes | t |
| | | **VOLUME** | | |
| tsp | teaspoons | 5 | milliliters | ml |
| Tbsp | tablespoons | 15 | milliliters | ml |
| fl oz | fluid ounces | 30 | milliliters | ml |
| c | cups | 0.24 | liters | l |
| pt | pints | 0.47 | liters | l |
| qt | quarts | 0.95 | liters | l |
| gal | gallons | 3.8 | liters | l |
| $ft^3$ | cubic feet | 0.03 | cubic meters | $m^3$ |
| $yd^3$ | cubic yards | 0.76 | cubic meters | $m^3$ |
| | | **TEMPERATURE (exact)** | | |
| °F | Fahrenheit temperature | 5/9 (after subtracting 32) | Celsius temperature | °C |

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



### Approximate Conversions from Metric Measures

| Symbol | When You Know | Multiply by | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| mm | millimeters | 0.04 | inches | in |
| cm | centimeters | 0.4 | inches | in |
| m | meters | 3.3 | feet | ft |
| m | meters | 1.1 | yards | yd |
| km | kilometers | 0.6 | miles | mi |
| | | **AREA** | | |
| $cm^2$ | square centimeters | 0.16 | square inches | $in^2$ |
| $m^2$ | square meters | 1.2 | square yards | $yd^2$ |
| $km^2$ | square kilometers | 0.4 | square miles | $mi^2$ |
| ha | hectares (10,000 $m^2$) | 2.5 | acres | |
| | | **MASS (weight)** | | |
| g | grams | 0.035 | ounces | oz |
| kg | kilograms | 2.2 | pounds | lb |
| t | tonnes (1000 kg) | 1.1 | short tons | |
| | | **VOLUME** | | |
| ml | milliliters | 0.03 | fluid ounces | fl oz |
| l | liters | 2.1 | pints | pt |
| l | liters | 1.06 | quarts | qt |
| l | liters | 0.26 | gallons | gal |
| $m^3$ | cubic meters | 35 | cubic feet | $ft^3$ |
| $m^3$ | cubic meters | 1.3 | cubic yards | $yd^3$ |
| | | **TEMPERATURE (exact)** | | |
| °C | Celsius temperature | 9/5 (then add 32) | Fahrenheit temperature | °F |

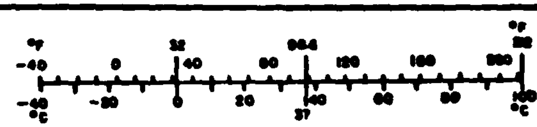


TABLE OF CONTENTS

## ABSTRACT

This study confirms that default data calculations can be used to develop ship hydrostatics, and strength information of suitable accuracy to allow the Coast Guard OSC (On Scene Coordinator) to make rapid and intelligent judgments of ship grounding incidents. The study recommends the calculations be performed on a small portable computer, which would be carried to the emergency site by the OSC, and would be fitted with graphic read-out capability for displaying numbers and simple sketches.

This study also performed hydrostatic calculations for a 200,000 DWT vessel trimmed to large angles. From the study of large trim angles, WCG found that hydrostatic values do not change significantly up to trim angles of 40% of draft. WCG results suggest that a vessel's hydrostatic data are not paticularly sensitive to changes in trim within reasonable ranges.

The study recommends the implementation of training using simplified calculations as an on-scene aid, but exposing OSC's and their teams to additional sources of hydrostatic and strength information as well. In addition, the training should include some theory of ship structures and hydrostatics.

## EXECUTIVE SUMMARY

The extraction of a grounded vessel or the alleviation of catastrophic pollution of a marine incident should be viewed as a complex engineering design process in which dozens of influences must be systematically analyzed and resolved on an ever improving spiral of information gathering and data analysis. This study verified that simple, well known data on a grounded ship can be used by a trained OSC to perform effectively the initial analysis or first cycle of salvage design. A previous study by ECO, Inc. under Coast Guard Contract No. DTCG23-82-R-20058 developed a computer based methodology for using simplified data to determine hydrostatics and hull loading for a grounded tanker.

In this study, The Washington Consulting Group (WCG) used default data or simplified data input to develop hydrostatic information for thirty-one tank ships and compared this to hydrostatic data developed by more precise methods. WCG found this data of sufficient accuracy to make an initial assessment of a tank ship stranding and to continue to monitor the salvage engineering as it progresses to completion. If more accurate information cannot be found, then the default data is sufficiently accurate to perform salvage analysis.

Default data based upon the use of hull coefficients such block coefficient (Cb), prismatic coefficient (Cp), and waterplane coefficient (Cw), have been used historically by naval architects in the preliminary design of ships. The computer

has allowed naval architects to obtain more accurate results quickly, thus reducing the importance of hull coefficients as design tools.

However, for emergency use or salvage analysis, hull coefficient or default data generated hydrostatic information is quite adequate. The OSC will be given a portable computer with which he can in effect perform the preliminary design of a ship and develop hydrostatic and hull loading information for salvage analysis. The value of the approach lies in the simplicity and availability of input data. To calculate default hydrostatics, the OSC must know:

| | | |
|---|---|---|
| a. | Length Between Perpendiculars | - LBP |
| b. | Beam of Vessel | - B |
| c. | Design Summer Draft | - dm |
| d. | Depth of Vessel | - D |
| e. | Speed in Knots [If not available use 15 knots] | - V |
| f. | Deadweight Capacity of Vessel | - DWT |
| g. | Age of Vessel | - year of construction |

This information is easily available in numerous marine publications such as Clarkson's The Tanker Register 1982, and for some ships, the Coast Guard's Marine Safety Information System. Using the above data, and a portable computer, the OSC

can generate salvage data in a few minutes, display the data to all interested parties and safely use the information to make intelligent decisions on salvage of the stranded tank vessel. This study made a check on the sensitivity of the default calculations to large trim angles by analyzing one large tank ship. Those single vessel calculations showed that the hydrostatic data were not sensitive to large angles of trim up to 40 percent of design draft.

At this time WCG suggests that the computer be selected and programmed, and the training of the OSC personnel be initiated. WCG does not suggest that an OSC equipped with a computer will become an instant salvage expert; however, the OSC as a leader of a large complex team can gain a rapid understanding of the stranded vessel and start the salvage design process. From the incidents reviewed and from information gained first hand from marine casualties, WCG has concluded that when the OSC has the necessary information and training he can control the tempo of the incident. The salvage thus moves at a sensible pace and the probability of success is greatly improved.

## ILLUSTRATIONS AND TABLES

## STATEMENT OF THE PROBLEM

### 1. Need for Modern Approach to Salvage

As stated in the previous work by ECO, Inc. (1) and by others in the salvage field, vessel salvage has been almost a "black art" and the salvage techniques are based more on methods that have worked in past salvage rather than a systematic analyis. As trade routes, vessels and products carried have changed, the approach to salvage must, also, change. As Admiral Sullivan wrote, "Salvage is a branch of engineering" which can be successful if planned "when there is complete appreciation of all of the factors influencing it." (2)

Those factors vary from changing social attitudes to advances in shipping technology. One of the anomalies of our affluent society is the simultaneous demand for more energy and a clean environment. We use vast amounts of petroleum energy, but at the same time demand that energy be transported safely. A few short years ago salvage involved saving the vessel; today the potential damage of releasing the cargo of a tanker far outweighs the value of the carrier. In addition, in recent years, major marine pollution incidents such as the Torrey Canyon and the Argo Merchant have increased public awareness of the dangerous environmental threats posed by cargo laden tankers.

Salvors today must be prepared not only to learn from experience, but also combine that experience with rapid communications, electronic sensors, and rapid computer based

calculations. Developing experience and expertise is still important, but real time complete analysis of any grounding is equally important.

2. <u>OSC's Need for Information for Timely Assistance</u>

The on-scene coordinator is the federal official placed in charge of an actual or potential oil pollution incident. His actions are followed closely by the media, anxious to keep a concerned public aware of major developments, which in many instances could have a direct economic impact on that public. Every action of the OSC, therefore, is subject to intense public scrutiny. In performing his functions, the OSC is assigned team members from various organizations, many of whom may not have been previously known to him. The OSC must, however form all of these persons into a cohesive group capable of assessing the hazard at hand and initiating actions to control and minimize any ensuing damage. The OSC's primary need is for information which is essential to sound decision-making. Since the salvage is a team effort, the information obtained should be in a format suitable for presentation to and understandable by all team members. Forming the disparate members of the group into an effective team is a major challenge to the OSC.

The OSC knows his geographic area of responsibility, but is probably not aware of specific hazards at the location of the grounding. Time of year of the grounding is important due to weather conditions and environmental changes. Time of day is

also important because of tide changes and safety hazards inherent in working at night. Personnel safety is a very important aspect of the salvage effort and one which requires the constant attention of the OSC.

Paradoxically, the stranded ship is perhaps the OSC's most important problem and his most important tool. Many of the ship's capabilities can be useful to the intelligent salvor. First, the main propulsion frequently has much more power than tugs and other assisting vessels can provide. Second, installed cargo pumps capable of off-loading a large tanker are larger and more efficient than any portable pumps which can be brought to the scene. Third, individual tanks on-board the grounded tanker may have many times the capacity of barges available for off-loading. Fourth, using ship's cargo pumps to transfer cargo from aft to forward or forward to aft may produce faster and more useful trim or draft changes in the grounded area than off-loading and offer far less danger of spills.

With the default data developed in this study and with modern portable computers, the OSC can determine rapidly the ship's hydrostatic characteristics and hull loadings. Such calculations do not solve all his problems, but they do allow him to assess the stranding, determine the size of the grounding force and look for solutions to reduce the grounding force until extraction is possible. In addition, the default calculations can

act as a check on more exacting calculations using a larger computer or Curves of Form Data. A simple, relatively accurate and quick analysis can give the OSC a feel for trends in the salvage operation under the direction of a salvage master. Such checks are helpful if the OSC is concerned about the success of salvage and is deciding whether or not to assume control of the salvage to prevent further damage. Success is either salvaging the vessel without loss of cargo or alleviating the potential hazard. Some decisions such as pumping a portion of the cargo into the water to save the hull from failure, require rapid, accurate calculations and can be considered only as a last resort.

3. Historical Sources of Salvage Information

Three recent cases, summarized below, involving salvage show the need for quick calculations and a recognition of the fact that salvage and hydrostatic calculations are an important part of the OSC's duties.

In case one, a chemical barge containing about 1,000 tons of a hazardous chemical had capsized and the chemical was thought to be in the barge. There were no drawings on the barge, but Marine Safety Office personnel sketched the barge arrangements by calling the inspector and the construction shipyard. Realizing the barge had excellent stability upside down, the OSC suggested the owners use two large floating cranes owned by the

Navy. The owners agreed and the equipment arrived on scene. The salvage master assigned by the owner was very cooperative with the OSC. After attempting to trip the barge upright by tugs with tow lines, the floating cranes were brought alongside and the barge righted. The incident lasted less than three days.

The preceeding case was successful due to the OSC's initial estimate that the barge could be righted by use of cranes. In other words, brief calculations and an intuitive sense of the hydrostatics of barges made the OSC confident of taking rapid action. There was cooperation and good rapport between the OSC, salvage master, and owners' representatives. In situations where the ship is more complex than a barge, the use of a computer and default analysis should develop the same sense of confidence and allow the salvage crew to take timely actions to alleviate or correct the grounding.

A second case involved a collision between a ship and a bridge. In this catastrophe one of the towers of the lift span of the damaged bridge rested on the ship. Ship and bridge remained entangled for over two weeks as actions were taken to strengthen the bridge and build piers to carry the load after the ship was removed. The number of people involved which included state and Federal representatives, ship owners, salvage crews, and maritime industry personnel made coordination very difficult. A salvage master was designated but was prevented from doing design

calculations of any sort by the terms of his contract and the insurance coverage of his company. The salvage concept did not consider using the ship in the system as a tool which could be changed hydrostatically or that the draft could be altered to reduce the stress and strains on the damaged bridge. What actually caused the second and final collapse of the bridge span has not been clearly determined; however, the continual stressing of the bridge due to tide changes were certainly harmful.

Later by rough calculations, the OSC found that the pumping capacity of the installed ballast pumps was sufficient to have compensated for the tidal changes. Simply estimating the tidal change in inches per hour, and computing or estimating TPI (tons per inch immersion) the OSC could have determined the amount of ballast to pump on or off. In this case, the ballast pumps had adequate capacity to hold the ship steady in space as the tidal changes in buoyancy were compensated for by adding or removing ballast water.

With the default data concept of this study the above calculations would have taken just a matter of minutes and could have been used in the decision making process of saving the bridge, reducing the danger to the salvage personnel involved and reducing the danger to the vessel. More important even than improving the ability to calculate the hydrostatics of the vessel is the concept that the OSC should use engineering evaluations in

salvage situations. In the ship-bridge incident, the OSC was not encouraged to participate in the technical aspects of salvage. In the approach used in this study, the OSC is being given the tools to be effective, but of greater importance is the encouragement for him to use engineering calculations to improve salvage in each situation.

A third case shows the need to monitor the salvage process and, also, the manner in which the salvage is being conducted. In this case, a tank barge broke loose from a tug and grounded on the beach near the Outer Banks of the Carolina coast. A mid-fall storm caused the accident, but the weather moderated and the OSC believed that about three weeks of good weather could be expected before the heavy winter storms dominated the area and made salvage attempts too hazardous to continue. Good weather prevailed longer than could have been expected for that time of year, but the salvage activities plodded along well into winter. Calculations were not made until pressure from the OSC caused the hiring of a naval architect. The OSC team with strike team members demonstrated that the barge would float if pulled off the beach and the naval architect concurred. Later, the barge was pulled from the beach, and did float at a draft predicted by calculations, but was lost later in the day in a violent fast moving winter storm near Cape Hatteras. Failure to use accepted engineering practices in the salvage caused heavy expenditures in

manpower and money. In addition, the failure to take advantage of good weather significantly reduced the probability of success.

### 4. Decision-Making and the Use of Modern Calculation Technology

The three examples discussed above are not intended to imply that a small computer and some calculations will solve all salvage problems. However, these examples do suggest that a marine incident brings together widely variant groups of interested people all advocating their own interests. Salvage is an engineering effort of many facets requiring both calculations and experience. An ability to produce calculations expedites the process and allows the OSC to focus the experience and intelligence of his team on a clearer and more attainable goal. In salvage the probability of success is never good and the portable computer is a tool the wise salvor will use to improve his chances of success.

## B. ANALYSIS OF THE PROBLEM

### 1. Previous Research

Ship design techniques have experienced rapid change since the digital computer became available in the 1950's. Large computers can now perform both hydrostatic and structural design in a short time from an input of ship's lines. However, to the salvor or the OSC, such information is not always available in a timely manner. Default data use a concept developed by naval architects in the pre-computer era where tables of parameters

such as block coefficient (Cb), waterplane coefficient (Cw) and prismatic coefficient (Cp) were in common usage in preliminary design. Such coefficients and other common parameters when used properly can produce results with sufficient accuracy to start the salvage engineering design "spiral" (3)in a timely manner. As more accurate calculations become available the salvage design can be improved.

A previous Coast Guard contract by ECO, Inc. produced (4) excellent results in determining design parameters and methods of finding hydrostatic data on a wide range of vessels. This current contract was intended to specialize in tank vessel analysis and to extend the number of tank vessels examined to provide more confidence in the default data calculations for tank vessels.

U.S. Navy Superintendent of Salvage is currently developing under contract a handbook which will provide salvage personnel with assistance in engineering a salvage design.

ECO, Inc., in their contract studied salvage approaches in use by other countries and discussed those approaches in their report.

## 2. Literature Search Method

In view of the work performed by ECO, Inc. (5), a Society of Naval Architects and Marine Engineers paper presented at the November, 1983 meeting of the Society in New York (6), and the discussions of that paper presented at the meeting, the

literature had been well researched and the effort should be concentrated on reviewing the tank vessels an OSC is likely to encounter today.

3. Ship Source Data Review

After looking to classification societies and owners, WCG found that ECO, Inc. had the best and most efficient file of current tanker data. Accordingly, ECO, Inc. was sub-contracted by WCG to analyze tankers in five categories of age and in five deadweight categories for a total of twenty-five tanker vessels of conventional design. The range of age and deadweight class was believed sufficient to cover conventional tank vessels. As will be discussed later, the correlation of default data compared well with Curves Of Form data developed from conventional naval architecture calculation techniques.

An additional six tankers of slightly different dimensions, for a "shallow draft" type tank vessel were analyzed. Calculations showed the default data would correlate with conventionally developed Curves of Form data.

Barges represent a new, more complex approach, primarily since barges vary so widely depending upon routes followed, shape, and location in a tow. Also a large ocean going barge has a ship shape making default data applicable. Generalized default data cannot be generated for such a category; however, some

insight on calculation data will be offered in another section of this study.

## 4. Review of Ship Design Techniques

Modern ship design techniques use large computer systems to determine hydrostatics, strength, damaged stability, propulsion requirements, and many other calculations. Before the introduction of the tremendous computing power of modern computing systems, the preliminary design calculations of a ship were made using comparisons of previous successfully designed ships through dimensionless parameters such as block coefficient (Cb), water plane coefficient (Cw) and prismatic coefficient (Cp). If carefully applied, such coefficients can be useful for predicting such characteristics as hydrostatics, stability, propulsion requirements, and so forth. In the present case, use of those preliminary design coefficients forms the basis of default data calculations. Since the OSC does not have the detailed calculations at hand, he literally performs a preliminary design on the stranded ship. The problems facing the salvor and the older naval architect are much the same. Naval architects used previous designs as a basis for designing a new ship to be built. Salvors, conversely already have a ship, but must estimate the ship design while developing the salvage engineering and searching for more complete data.

## C. DATA GATHERING METHODOLOGY

### 1. Analysis of Hydrostatic Default Data

The work by ECO, Inc. had shown the default data methodology using standard parameters for calculation inputs was suitable for the initial analysis of a grounding and could be useful in a wide range of other marine incidents as well. In this current study, WCG was required to look more closely at tank vessels, improve the development of the default parameters and check the validity of the techniques using a wider range of tank vessels in the comparison. After a review of data sources such as classification societies, Coast Guard data, and discussion with ECO, Inc., WCG found that ECO, Inc. had not only the best resource of available tanker data but also a format which could be efficiently used. In addition to the ship data in the ECO, Inc. files, WCG obtained hyrostatic data on other tank vessels of slightly different design. This permitted checking to a further extent the application of the default data analysis.

### 2. Analysis of Hull Structure Data

Detailed structural analysis of a ship's hull is a complex process which requires using classification society rules in designing each ship component, such as frames, longitudinals and shell plating. In common practice today is the use of analysis programs in large computers to determine structural adequacy. Such programs are not readily adaptable to default analysis of

ship structures. However, regardless of the analysis technique used by the designer, the ship structure must be designed to withstand a minimum bending moment and shear load. The bending moment and shear forces the hull girder must resist are caused by the differences in hull weight and cargo loading (these are the "down" loads"), and buoyancy and grounding reaction forces (which are the "up" loads). The difference between the buoyancy or "up" forces and gravity or "down" forces is the loading the ship's hull girder must carry. To be classified or approved, the vessel must meet the minimum strength requirements which are listed as minimum BM and minimum shear the hull design must withstand; hence, the OSC can use those minimums published by the classifications societies to examine the grounded hull load conditions. In other words, the default analysis does not design the hull, but it finds a bending moment and shear which will be less or equal to the bending moment and shear values used by the structural designers in their detailed hull design. The American Bureau of Shipping suggests for the early design stages a still water Bending Moment Calculation:

Bending Moment Calculation[7]

$$M_s = C_{st}L^{2.5}B(C_b+0.5) \text{ where } C_{st} = \left(0.312+\frac{360-L}{2990}\right)10^{-3} \quad 200\leq L\leq 360 \text{ ft.}$$

$$= \left(0.285+\frac{525-L}{6100}\right)10^{-3} \quad 360< L\leq 525 \text{ ft.}$$

$$= \left(0.275+\frac{690-L}{16400}\right)10^{-3} \quad 525< L\leq 690 \text{ ft.}$$

$$= (.275)10^{-3} \quad 690< L\leq 820 \text{ ft.}$$

$$= \left(.275-\frac{L-820}{11600}\right)10^{-3} \quad 820< L\leq 1400 \text{ ft.}$$

$L$ = The distance in feet on the estimated summer load line, from the fore side of the stem to the after side of the rudder post or stempost; where there is no rudder post or sternpost, L is to be measured to the centerline of the rudder stock. For use with the ABS Rules, L is not to be less than 96% and need not be greater than 97% of the length on the summer load line.

$B$ = The greatest molded breadth in feet.

$C_b$ = Block coefficient at summer load waterline, based on the length L. For this equation, $C_b$ is not to be taken as less than 0.64.

ABS suggests a shear force should be less than $\frac{5.0\ Ms}{L}$ While such values may not be rigorous, they seem satisfactory for default calculations. It is likely the vessel will more than meet those minimum requirements; hence, a structural refinement beyond that value is not believed to be practical for default analysis. If the grounding incident continues, the OSC should be able to find either on board the ship or at the owner's office a loading manual or a load determining device such as "loadmaster" developed and patented by various companies, which applies to the specific standard ship.

### 3. Data Required to Conduct an Assessment of a Stranded Ship

For initial assessment of the hydrostatics of a floating vessel the OSC need only input:

| | | |
|---|---|---|
| a. | Length Between Perpendiculars | - LBP |
| b. | Beam of Vessel | - B |
| c. | Design Summer Draft | - dm |
| d. | Depth of Vessel | - D |
| e. | Speed in Knots | - V |
| f. | Deadweight Capacity of Vessel | - DWT |
| g. | Age of Vessel | - year of construction |

If speed is not known, use 15 knots which should be close to the design speed of a majority of tankers in service today.

All of the above information is available in classification society publications, Clarkson's The Tanker Register (year), and the Coast Guard Marine Safety Information System. With a properly programmed portable computer and the above information a trained OSC is in a position to start the first cycle of a marine incident analysis or a check review of the work of others.

D. DEFAULT DATA CALCULATION TECHNIQUES

1. Analysis of Calculation Methods

The ECO, Inc. study previously discussed, covered a wide range of vessel types, and used traditional means to generate block coefficient and water plane coefficient. In the current study which was directed towards tank vessels, both deadweight to displacement ratio values and age played the most important role in ship design. Accordingly the vessels were categorized as shown in Tables 1 and 2.

TABLE 1

AGE GROUP CATEGORIES

| AGE GROUP | YEAR BUILT |
|---|---|
| A1 | 1975 - 1982 |
| A2 | 1970 - 1974 |
| A3 | 1965 - 1969 |
| A4 | 1960 - 1964 |
| A5 | Pre 1960 |

TABLE 2

DEADWEIGHT CLASS CATEGORIES

| DEADWEIGHT CLASS | DEADWEIGHTS INCLUDED |
|---|---|
| D1 | 6,000 - 19,999 |
| D2 | 20,000 - 49,999 |
| D3 | 50,000 - 99,999 |
| D4 | 100,000 - 199,999 |
| D5 | 200,000 and greater |

Using the above categories, the default characteristics are developed using the evaluation methods as follows.

1. Displacement calculated as follows:

   a. Enter deadweight class (D1 . . . D5) as per Table 2;

   b. For each Dn, find deadweight to displacement ratio by appropriate formula from Table 3 where Dwt = full load deadweight;

   c. Divide deadweight by deadweight to displacement ratio calculated in 1.b; output is displacement at full load.

2. Block Coefficient (Cb) calculated as follows:

   a. Cb = ((displacement) x 35)/(L x B x dm)

   Where, 35 $ft^3$/long ton = Conversion Factor

   L = Length Between Perpendiculars in feet

   B = Extreme Breadth in feet

   dm = Full Load Midships Draft in feet

3. Waterplane Coefficient (Cw) is calculated by the appropriate formula from Table 3 using the appropriate age group (A1 . . . . .A5) and deadweight class (D1 . . . D5).

4. Prismatic Coefficient (Cp) is calculated as follows:

a. $Cp = (0.917 \times Cb) \times .073$

5. Transverse Metacenter (KM) is calculated as follows:

a. KM (in feet) = $(Cw/(Cw + Cb)) \times dm + (B^2 \times (0.125 \times Cw - 0.045))/(dm \times Cb)$.

6. Tons Per Inch immersion (TPI) is calculated as follows:

a. TPI (in tons) = $(L \times B \times Cw)/420$,
where 35 $ft^3$/long ton x 12 inches/foot = conversion factor.

7. Moment To Trim 1 Inch (MT1) is calculated as follows:

a. MT1 (in foot-tons) = $(B \times L^2 \times (0.143 \times Cw - 0.0659))/420$

8. Longitudinal Center of Buoyancy (LCB) is calculated as follows:

a. LCB (in feet from forward perpendicular (FP)) = $L \times (0.5-(0.175 \times Cp-0.125))$.

9. Longitudinal Center of Flotation (LCF) is calculated as follows:

a. LCF (in feet from FP) = 0.5 x Lx (V/160 + 0.914)

where V = service speed in knots.

2. Default calculation verification

Thirty-one tank ships were used in the verfication process. Twenty-five came from the files of ECO, Inc., and an additional six of a more shallow draft design were included in the development studies. At least one vessel from each age category was analyzed in each deadweight category. Hence, in the twenty-five vessel matrix at least one vessel was sampled in each category. Additional vessels were used as double checks in the various groups.

The ECO, Inc. studies showed that deadweight to displacement (DWT/Displacement) ratio varies with deadweight class, but was not influenced by age. At first glance this was surprising, but on reflection one realizes the ships are designed to the same load-line convention. While important in detailed ship design, the use of high-strength steels and single deckhouse arrangements are not major influences in lightship weight and are not significant in default calculations. Hence, the deadweight/displacement ratio which is:

$$\frac{\text{displacement} - \text{light ship weight}}{\text{displacement}}$$

is a good parameter where lightship weight correlates well with ship size or displacement. Even the shallower draft designs can be correlated. It is thought that vessels with higher L/D ratios would have more steel weight due to a thinner hull girder; however this does not seem to have an impact and in some cases the block-like form creates more deadweight or cargo carrying capacity than the conventional designs.

ECO, Inc. studies verified by WCG vessel input showed waterplane coefficient (Cw) varied with both age and deadweight class and correlated with length and beam. ECO data demonstrated that deadweight to displacement ratio varies with deadweight class but not age (all ships, regardless of age, comply with the same loadline convention, and the use of high strength steels and single deck house is "noise" in light ship weight in the case of newer ships.)

Waterplane coefficient varies with both age group and deadweight class and in general, appears to follow the variance in length to beam ratio. Comparing actual full load values for displacement, KM, TPI, MT1, LCB, and LCF of twenty-five (25) tankers of various age groups (A) and deadweight classes (D) with corresponding estimated values gave errors of:

| | Average Error | Maximum Error |
|---|---|---|
| Displacement | 0.8% | 7.8% |
| KM | 1.17% | 11.6% |

| | | |
|---|---|---|
| TPI | 0.2% | 4.5% |
| MT1 | 1.25% | 10.7% |
| LCB | 0.54% | 2.7% |
| LCF | 0.45% | 2.7% |

Additional vessels of slightly different design which were sampled by WCG using the same techniques, showed the following values:

| | Average Error | Maximum Error |
|---|---|---|
| Displacement | 3.2% | 7.0% |
| KM | 9.3% | 14.3% |
| TPI | 2.7% | 9.8% * |
| MT1 | 8.9% | 20.3% * |
| LCB | 1.1% | 1.4% |
| LCF | 0.5% | .6% |

(*) - The large error was due to a shallow draft vessel with a wide beam. The Cw for this blunt, block-like vessel was calculated with a 10% error which was also reflected in the TPI and the MT1. For this type vessel the OSC should make a special attempt to find the hull coefficients.

Deadweight to displacement ratio values used in displacement calculations and the formulas for computing waterplane coefficients are shown in Table 3. With the level of verification from the vessels in this study, WCG recommends that the tables in Table 3 be used in default data calculations on tanker vessels.

3. High Trim Angle Studies

In stranding and other kinds of marine incidents, the possibility exists that the vessel could assume large trim angles either at grounding or during tide changes. At the beginning of this study, WCG was concerned whether or not the default data generation methods could calculate useable hydrostatic values at large angles of trim. To allay this concern without the expense of sampling several vessels using major naval architecture programs such as the Ships Hull Characteristic Program (SHCP), WCG decided to sample one representative vessel. If the results showed significant change in hydrostatic characteristics with trim, then WCG would have undertaken a more comprehensive analysis on a series of vessels. If the hydrostatic values on the other hand were not sensitive to large trim angles, then the more detailed studies could be deferred until a later date.

WCG found that ECO, Inc. had enough information on file to run one tanker of approximately 200,000 deadweight tons through large trim angles to a trim of 40 percent of full mean draft.

## DEADWEIGHT TO DISPLACEMENT RATIO

| D1 | D2 | D3 | D4 | D5 |
|---|---|---|---|---|
| ((.0016*DWT/1000))+.717 | ((.00128*DWT/1000))+.725 | ((.00096*DWT/1000))+.746 | ((.00031*DWT/1000))+.813 | ((.000037*DWT/1000))+.866 |

## CALCULATION OF WATERPLANE COEFFICIENT

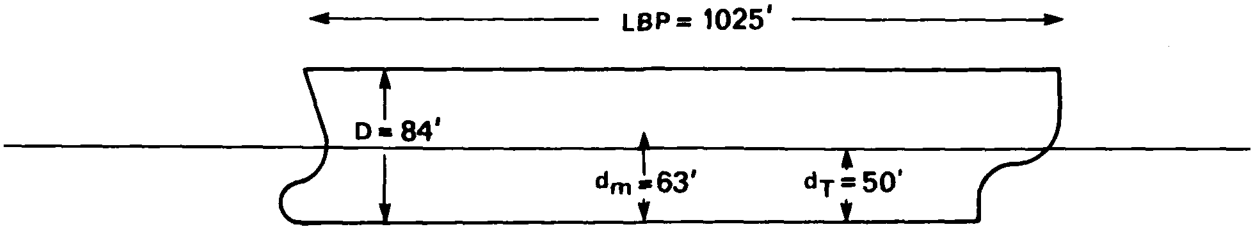
| | D1 | D2 | D3 | D4 | D5 |
|---|---|---|---|---|---|
| A1 | $\frac{((1.083*DWT)+ 9452)}{(Length*Beam)}$ | $\frac{((.853*DWT)+ 18099)}{(Length*Beam)}$ | $\frac{((.708*DWT)+ 24280)}{(Length*Beam)}$ | $\frac{((.506*DWT)+ 44795)}{(Length*Beam)}$ | $\frac{((.488*DWT)+ 43268)}{(Length*Beam)}$ |
| A2 | $\frac{((1.251*DWT)+ 9234)}{(Length*Beam)}$ | $\frac{((.725*DWT)+ 18749)}{(Length*Beam)}$ | $\frac{((.656*DWT)+ 31472)}{(Length*Beam)}$ | $\frac{((.509*DWT)+ 44847)}{(Length*Beam)}$ | $\frac{((.335*DWT)+ 71229)}{(Length*Beam)}$ |
| A3 | $\frac{((1.21*DWT)+ 9514)}{(Length*Beam)}$ | $\frac{((.698*DWT)+ 20392)}{(Length*Beam)}$ | $\frac{((.706*DWT)+ 29471)}{(Length*Beam)}$ | $\frac{((.56*DWT)+ 41325)}{(Length*Beam)}$ | $\frac{((.594*DWT)+ 19428)}{(Length*Beam)}$ |
| A4 | $\frac{((1.36*DWT)+ 8406)}{Length*Beam)}$ | $\frac{((.993*DWT)+ 14217)}{(Length*Beam)}$ | $\frac{((.755*DWT)+ 24424)}{(Length*Beam)}$ | $\frac{((.552*DWT)+ 40779)}{(Length*Beam)}$ | $\frac{((.608*DWT)+ 19890)}{(Length*Beam)}$ |
| A5 | $\frac{((1.241*DWT)+ 8033)}{(Length*Beam)}$ | $\frac{((1.045*DWT)+ 10201)}{Length*Beam)}$ | $\frac{((.713*DWT)+ 23062)}{(Length*Beam)}$ | $\frac{((.521*DWT)+ 38474)}{(Length*Beam)}$ | $\frac{((.579*DWT)+ 18948)}{(Length*Beam)}$ |

Table 3

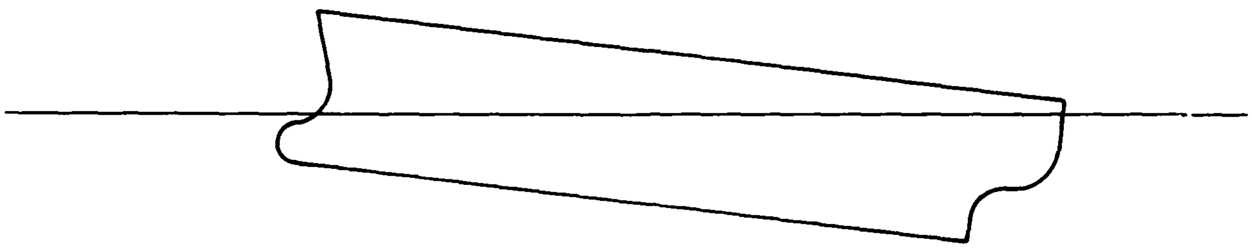
That is, a vessel of 60 feet draft the 40% trim would be 24 feet or about a 12 feet change in draft forward and about 12 feet change in draft aft. The ECO results of the single ship calculations, which are graphically depicted in Figure 1, showed that for trims of up to 40 percent of full load mean draft:

- Displacement increases with trim but less than one percent for either forward or aft trim.
- KM varies less than two percent for forward or aft trim.
- TPI varies less than one percent for either forward or aft trim.
- MT1 increases by approximately five percent for after trim and decreases by approximately six percent for forward trims.
- LCB varies approximately two percent forward for trim forward and two plus percent aft for trims aft.
- LCF varies by approximately one percent forward for forward trims and less than one percent aft for after trims.
- Deck does not submerge.
- Neither bulbous bow nor stern portion of keel emerges.

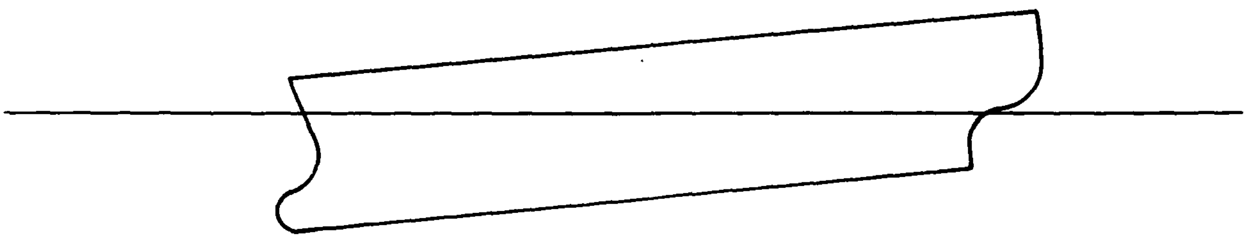
The study of large trim showed that while hydrostatic values do change with trim, they may not be highly sensitive to relatively large angles of trim. While no firm conclusions should be drawn from a single ship sample, it does suggest for default data type calculations, additional vessel studies are not justified at this time, and that hydrostatic data developed by default data at




VESSEL ON AN EVEN KEEL – NO TRIM



VESSEL TRIMMED BY THE STERN 24'



VESSEL TRIMMED BY THE BOW 24'

<u>TEST VESSEL DESCRIPTION</u>

LENGTH BETWEEN PERPENDICULARS = LBP = 1025' (with a bulbous bow)

MOLDED DEPTH = D = 84'

DESIGN DRAFT = $d_m$ = 63'

TEST DRAFT = $d_T$ = 50'

MAXIMUM TRIM = 60' x 40% = 24'

<u>NOTE</u>: DURING THE TEST – deck did not submerge
– neither bulbous bow nor stern portion of keel emerged

LARGE TRIM ANGLE STUDY – Figure 1

even keel can be used at large angles of trim up to about 40% of design draft provided the vessel initially was operating near its design draft. If the trim were to immerse large portions of top watertight deck or at light drafts if a large portion of the underwater body should be emersed (come out of the water) then default data should be used with care.

E. DISCUSSION OF PROBLEM SOLUTION

1. WCG's effort has been directed to reducing the number of data inputs the OSC needs to develop hydrostatic data of sufficient accuracy to conduct his initial review of the grounded ship and to monitor the progress of others who are more performing more elaborate calculations. WCG's method of accomplishing this goal was to collect as much data as possible from existing ships in a wide range of age and size where the hydrostatic data had been developed by more precise means. Hydrostatic information developed by default calculations was compared to the existing data. The amount of deviation of the default data is considered a good compromise between timeliness and accuracy of the data.

In WCG's study, constant attention was required to avoid complicating calculations by using greater accuracy than necessary in hydrostatics, and too many inputs. More accurate hydrostatic calculations can generally be found on board the ship or later at

the owner's office. In the beginning, however, obtaining information quickly is very important to the proper control of a marine casualty.

2. The most significant problems came in obtaining the stability information for comparison. While a large amount of hydrostatic information has been prepared, the information is proprietary and must be processed in such a way to prevent tracing it back to its source.

## F. DISCUSSION OF DEFAULT CALCULATION USAGE

### 1. Equipment Suggested

To use default calculations properly, a small, handy, rugged, portable computer is considered to be necessary. Many of the default calculations could be performed by hand calculator or by use of paper and pencil; however, the time needed to perform the calculations and the work space necessary to assemble the information would render such a procedure impractical. Frequently, ships run aground at remote places during cold, rainy, windy weather, hence working space time and habitability are rarely found at the early stages of an incident. In addition to performing calculations, the computer should have a graphic display capability for use by the OSC and available to the other members of his team and other interested parties. As an individual who must convince others more often than issue

direct orders, the ability to display and discuss the findings is very important to the OSC's effectiveness, and to his ability to educate and influence those around him.

Programs developed for the computer should be kept as simple as possible and allow rapid checking or initial calculations with as few inputs as possible. Simplicity of use and speed of results are very important to the OSC, who has great demands on his time from a myriad of sources and requires rapid support for his decision-making process.

2. Training Required

The amount of training time required to use the computer and generate hydrostatic calculations should be relatively short and can, almost, be self-taught from interactive questions posed by the computer itself. Use of computer general data and a sense of understanding of a complex ship stranding problems is a completely different question. To understand properly the complete problem, there is a need to understand naval architecture and ship structures, not necessarily from an academic aspect, but from a practical one. The OSC should have a sense of right and wrong for his actions and some understanding of the physical significance of the data generated. Those students who visualize objects or things in three diminsions or those who understand moments and levers in three dimensions, find naval architecture

laborious but understandable. Unfortunately, those individuals, whether students or mariners, who are limited in three dimensional visualization find both the academic and the practical approach difficult and must resort to notes and rules or a cookbook approach for successful vessel casualty decision-making.

The training program needed should include some theory and substantial practical experience in making default calculations and visualizing the impact of decisions on the stranded ship. In addition the training should include use of Curves Of Form, Trim and Stability Booklets, stress numerical calculations and some of the patented hull stress calculation devices in common usage today. As often stated in the field of marine salvage, professional salvage personnel and salvage masters require many years of training and practical experience to become proficient; hence one should not expect a short course to allow an individual to develop a full understanding of the problem. However, a well presented training course should develop a sense of understanding of the stranding problem by the OSC, allow him to take certain obvious corrective actions, and permit him to monitor the actions of others.

A very important part of the grounding question is the ability to take soundings of the water depth, drafts of the vessel, ullages of the tanks and free boards of the vessel. Poor information put into the computer will make drastic differences in the grounding forces and, as a result, in hull stress.

3. Information Manuals

Computer manuals should be short, simple and small for ease of carrying to the scene. Interactive computer language or graphics should be used in almost all cases to allow the OSC to develop hydrostatic and structural data.

Training manuals should be developed for an initial course and made available on a continuing basis for unit training and training the OSC's team. A long range training and education program will be necessary to give the OSCs the confidence to make proper use of their ability to develop naval architecture data, interpret the results and take corrective action to alleviate the danger in a grounding situation.

G. CONCLUSIONS

1. The satisfactory comparison of hydrostatic results generated by default calculations and the results generated by other more detailed traditional calculations for the tank vessels included in this study, show the default calculation method is suitable for initial evaluation of grounding incidents. It is also suitable for monitoring the more detailed calculations as the incident progresses.

2. Based on incidents studied, the use of default calculation will improve the effectiveness of the OSC's performance in grounding and similar incidents, and can be instrumental in causing the salvage to proceed in a businesslike manner.

## H. RECOMMENDATIONS

1. Sufficient study of the default calculations has been made at this time to start the computer selection process and the user program development.

2. In addition, the OSC and OSC team training program should be developed and put into use.

3. Later, after the training has started, and some experience has been gained by field personnel with actual incidents, additional vessel designs should be studied.

4. Since weight movements on board ship should be reflected in visible draft changes, the OSC can use this as a way to check the results of his actions on the hydrostatics of the vessel. However, if the OSC moves weights, this will be shown as bending moment and shear force changes from the calculations generated by the computer. The visual response of the hull girder to load changes are much more subtle. In addition, had the vessel been badly damaged on grounding, the hull girder's ability to carry load would have been much diminished. The OSC's ability to determine hull structural damage is always difficult if not impossible, first because of cargo in the tanks hiding the inside of the hull, and secondly, since the exterior of the hull is likely to be hidden by the ground on which the vessel is resting.

The only visible hull girder response will be tensile stress, buckling or some other failure mode or by variations in

hog or sag. Accordingly, the computer programming and personnel training should consider accurate monitoring of hog and sag. Future research or study should be initiated to develop "thumb rules" on hog or sag. These rules will be useful in advising the OSC either that loading is excessive and suggesting that he recheck the load, or that the hull girder is damaged. If the hull girder has failed, it will not carry additional load, and any action will create an erratic response which may cause salvage personnel to make improper judgments.

## REFERENCES


1. Joseph D. Porricelli and J. Huntley Boyd, Jr., Analytical Techniques for Predicting Grounded Ship Responses (Washington, D.C.: Ship Structure Committee, 1983, SR 1294).

2. W.A. Sullivan, "Marine Salvage", transport of The Society Naval Architects and Marine Engineers, V.56, (New York: SNAME, 1948).

3. G. R. Beakley and H.W. Leach, Principles of Engineering Design, 2nd ed. (New York: McMillan, 1972).

4. Analytical Techniques.

5. Ibid.

6. Joseph D. Porricelli, J. Huntley Boyd, Jr., and Keith E. Schleiffer, "Modern Analytical Techniques in Salvage Engineering Using Portable Computers" (annual meeting of The Society of Naval Architects and Marine Engineers, New York, N.Y., 1983).

7. American Bureau of Shipping, Rules for Building and Classing Steel Vessels, Section 6/3-4 (New York, N.Y.: ABS, 1982).

# APPENDIX A

Default Hydrostatic Data
Compared with Hydrostatic
Data Developed by More
Precise Techniques

DEADWEIGHT 39232
LENGTH 660
BEAM 90
DEPTH 47
DRAFT 35.05
SPEED 16
AGE GROUP 1
DWT GROUP 2

DISPLACEMENT 50607.8
BLOCK COEFF .850767
WATERPLANE COEFF .868079
PRISMATIC COEFF .853154
KM 34.953
 ACTUAL VALUE 36.74
TPI 122.771
 ACTUAL VALUE 123.3
MT1 5435.85
 ACTUAL VALUE 5438
LCB 313.961
 ACTUAL VALUE 313.25
LCF 334.62
 ACTUAL VALUE 330.8

DEADWEIGHT 172775
LENGTH 864.2
BEAM 172.9
DEPTH 74.99
DRAFT 57.32
SPEED 15.6
AGE GROUP 1
DWT GROUP 4

DISPLACEMENT 199380
BLOCK COEFF .81477
WATERPLANE COEFF .884882
PRISMATIC COEFF .820144
KM 71.8394
 ACTUAL VALUE 72.3
TPI 314.808
 ACTUAL VALUE 317.4
MT1 18643.2
 ACTUAL VALUE 19138.8
LCB 416.091
 ACTUAL VALUE 410.75
LCF 437.069
 ACTUAL VALUE 437.91

DEADWEIGHT 264073
LENGTH 1060
BEAM 178
DEPTH 86
DRAFT 67.16
SPEED 15.8
AGE GROUP 1
DWT GROUP 5

DISPLACEMENT 301532
BLOCK COEFF .832847
WATERPLANE COEFF .912315
PRISMATIC COEFF .83672
KM 74.2167
  ACTUAL VALUE 73.94
TPI 409.847
  ACTUAL VALUE 418
MT1 30743.5
  ACTUAL VALUE 31956
LCB 507.288
  ACTUAL VALUE 501.8
LCF 536.758
  ACTUAL VALUE 525.5

DEADWEIGHT 400219
LENGTH 1148.3
BEAM 229.7
DEPTH 92.16
DRAFT 72.67
SPEED 16.35
AGE GROUP 1
DWT GROUP 5

DISPLACEMENT 454377
BLOCK COEFF .829684
WATERPLANE COEFF .9045
PRISMATIC COEFF .833821
KM 97.4635
  ACTUAL VALUE 97.4
TPI 568.035
  ACTUAL VALUE 578.59
MT1 45751.9
  ACTUAL VALUE 49130.2
LCB 550.129
  ACTUAL VALUE 538.1
LCF 583.444
  ACTUAL VALUE 575.51

DEADWEIGHT 415000
LENGTH 1182.4
BEAM 226.4
DEPTH 94.2
DRAFT 75.1
SPEED 16
AGE GROUP 1
DWT GROUP 5

DISPLACEMENT 470866
BLOCK COEFF .819756
WATERPLANE COEFF .918163
PRISMATIC COEFF .824716
KM 97.766
  ACTUAL VALUE 93.4
TPI 585.209
  ACTUAL VALUE 568.29
MT1 49285.1
  ACTUAL VALUE 46924
LCB 568.35
  ACTUAL VALUE 553.57
LCF 599.477
  ACTUAL VALUE 587.28

DEADWEIGHT 22368
LENGTH 498.65
BEAM 77.07
DEPTH 41.83
DRAFT 31.99
SPEED 14.2
AGE GROUP 2
DWT GROUP 2

DISPLACEMENT 29680.3
BLOCK COEFF .84497
WATERPLANE COEFF .909834
PRISMATIC COEFF .847837
KM 31.689
  ACTUAL VALUE 31.4
TPI 83.2519
  ACTUAL VALUE 80.25
MT1 2929.58
  ACTUAL VALUE 2697
LCB 237.671
  ACTUAL VALUE 239.41
LCF 250.011
  ACTUAL VALUE 254.53

DEADWEIGHT 38371
LENGTH 599.99
BEAM 89.99
DEPTH 48.26
DRAFT 35.01
SPEED 15.75
AGE GROUP 2
DWT GROUP 2

DISPLACEMENT 49567.6
BLOCK COEFF .917773
WATERPLANE COEFF .86248
PRISMATIC COEFF .914598
KM 32.7916
  ACTUAL VALUE 36.7
TPI 110.876
  ACTUAL VALUE 114.88
MT1 4430.03
  ACTUAL VALUE 4835.6
LCB 278.963
  ACTUAL VALUE 286.39
LCF 303.726
  ACTUAL VALUE 302.15

DEADWEIGHT 70213
LENGTH 786
BEAM 105.23
DEPTH 57
DRAFT 43.51
SPEED 15.7
AGE GROUP 2
DWT GROUP 3

DISPLACEMENT 86319.9
BLOCK COEFF .839514
WATERPLANE COEFF .937384
PRISMATIC COEFF .842834
KM 44.8327
  ACTUAL VALUE 43.8
TPI 184.599
  ACTUAL VALUE 178.8
MT1 10548.1
  ACTUAL VALUE 9960
LCB 375.318
  ACTUAL VALUE 375.5
LCF 397.765
  ACTUAL VALUE 397.75

DEADWEIGHT 75600
LENGTH 763
BEAM 125
DEPTH 54.5
DRAFT 41.2
SPEED 16.8
AGE GROUP 2
DWT GROUP 3

DISPLACEMENT 92355.5
BLOCK COEFF .82262
WATERPLANE COEFF .849967
PRISMATIC COEFF .827342
KM 49.1726
  ACTUAL VALUE 52.67
TPI 193.013
  ACTUAL VALUE 200.2
MT1 9641.36
  ACTUAL VALUE 10222
LCB 366.404
  ACTUAL VALUE
LCF 388.748
  ACTUAL VALUE

DEADWEIGHT 120476
LENGTH 850
BEAM 138.7
DEPTH 68
DRAFT 51.75
SPEED 16
AGE GROUP 2
DWT GROUP 4

DISPLACEMENT 141679
BLOCK COEFF .812768
WATERPLANE COEFF .900541
PRISMATIC COEFF .818308
KM 58.1046
  ACTUAL VALUE 55
TPI 252.784
  ACTUAL VALUE 253.9
MT1 15002.3
  ACTUAL VALUE 15500
LCB 409.527
  ACTUAL VALUE 404
LCF 430.95
  ACTUAL VALUE 428.75

DEADWEIGHT 212000
LENGTH 1026.75
BEAM 158.25
DEPTH 85.97
DRAFT 63.42
SPEED 16
AGE GROUP 2
DWT GROUP 5

DISPLACEMENT 242606
BLOCK COEFF .824015
WATERPLANE COEFF .875469
PRISMATIC COEFF .828622
KM 63.5473
  ACTUAL VALUE 64.23
TPI 338.688
  ACTUAL VALUE 346.7
MT1 23551.6
  ACTUAL VALUE 24734
LCB 492.831
  ACTUAL VALUE 486.2
LCF 520.562
  ACTUAL VALUE 511.4

DEADWEIGHT 225281
LENGTH 1046.54
BEAM 143.5
DEPTH 91
DRAFT 70.17
SPEED 17.5
AGE GROUP 2
DWT GROUP 5

DISPLACEMENT 257660
BLOCK COEFF .855767
WATERPLANE COEFF .976825
PRISMATIC COEFF .857738
KM 63.8431
  ACTUAL VALUE 60.3
TPI 349.281
  ACTUAL VALUE 333
MT1 27611.4
  ACTUAL VALUE 26750
LCB 496.997
  ACTUAL VALUE 500.9
LCF 535.501
  ACTUAL VALUE 530.8

DEADWEIGHT 257034
LENGTH 1049.5
BEAM 169.9
DEPTH 87.56
DRAFT 68.57
SPEED 14.85
AGE GROUP 2
DWT GROUP 5

DISPLACEMET 293582
BLOCK COEFF .840403
WATERPLANE COEFF .88237
PRISMATIC COEFF .843649
KM 67.8281
  ACTUAL VALUE 69.5
TPI 374.608
  ACTUAL VALUE 385.4
MT1 26858
  ACTUAL VALUE 28774.5
LCB 500.991
  ACTUAL VALUE 496.5
LCF 528.325
  ACTUAL VALUE 524.72

DEADWEIGHT 21076
LENGTH 528.2
BEAM 90.12
DEPTH 39.76
DRAFT 30.77
SPEED 13.9
AGE GROUP 3
DWT GROUP 2

DISPLACEMENT 28027.4
BLOCK COEFF .669737
WATERPLANE COEFF .737438
PRISMATIC COEFF .687149
KM 34.7189
  ACTUAL VALUE 31.1
TPI 83.5787
  ACTUAL VALUE 80.39
MT1 2367.85
  ACTUAL VALUE 2651
LCB 266.608
  ACTUAL VALUE 253.56
LCF 264.331
  ACTUAL VALUE 268.86

DEADWEIGHT 37814
LENGTH 630
BEAM 90.08
DEPTH 48.83
DRAFT 36.64
SPEED 15.5
AGE GROUP 3
DWT GROUP 2

DISPLACEMENT 48893.1
BLOCK COEFF .822984
WATERPLANE COEFF .82442
PRISMATIC COEFF .827676
KM 33.9578
ACTUAL VALUE 37.05
TPI 111.396
ACTUAL VALUE 116.8
MT1 4425.86
ACTUAL VALUE 4850
LCB 302.499
ACTUAL VALUE 304.25
LCF 318.426
ACTUAL VALUE 318.6

DEADWEIGHT 111052
LENGTH 859.9
BEAM 136.2
DEPTH 62.99
DRAFT 45.47
SPEED 17.2
AGE GROUP 3
DWT GROUP 4

DISPLACEMENT 131046
BLOCK COEFF .861277
WATERPLANE COEFF .883842
PRISMATIC COEFF .862791
KM 54.0458
ACTUAL VALUE 56.0
TPI 246.462
ACTUAL VALUE 244.5
MT1 14504.5
ACTUAL VALUE 14090.7
LCB 407.603
ACTUAL VALUE 407.29
LCF 439.194
ACTUAL VALUE 429.70

DEADWEIGHT 249952
LENGTH 1080
BEAM 169.9
DEPTH 83.99
DRAFT 65.42
SPEED 16.5
AGE GROUP 3
DWT GROUP 5

DISPLACEMENT 285578
BLOCK COEFF .832656
WATERPLANE COEFF .915023
PRISMATIC COEFF .836546
KM 71.0164
  ACTUAL VALUE 70.7
TPI 399.761
  ACTUAL VALUE 400.85
MT1 30645
  ACTUAL VALUE 31337.9
LCB 516.893
  ACTUAL VALUE 513.14
LCF 549.247
  ACTUAL VALUE 545.8

DEADWEIGHT 47200
LENGTH 705
BEAM 102
DEPTH 50
DRAFT 37.7
SPEED 17.5
AGE GROUP 4
DWT GROUP 2

DISPLACEMENT 60095.5
BLOCK COEFF .775854
WATERPLANE COEFF .849487
PRISMATIC COEFF .784458
KM 41.4675
  ACTUAL VALUE 41.5
TPI 145.444
  ACTUAL VALUE 149
MT1 6708.43
  ACTUAL VALUE 7005
LCB 343.843
  ACTUAL VALUE 340.8
LCF 360.74
  ACTUAL VALUE

DEADWEIGHT 47500
LENGTH 705
BEAM 102
DEPTH 50
DRAFT 38.5
SPEED 16
AGE GROUP 4
DWT GROUP 2

DISPLACEMENT 60448
BLOCK COEFF .764187
WATERPLANE COEFF .85363
PRISMATIC COEFF .773759
KM 42.1341
  ACTUAL VALUE 41.2
TPI 146.154
  ACTUAL VALUE 143
MT1 6779.94
  ACTUAL VALUE 6350
LCB 345.162
  ACTUAL VALUE 340.9
LCF 357.435
  ACTUAL VALUE 356.1

DEADWEIGHT 19183
LENGTH 535
BEAM 75
DEPTH 40.5
DRAFT 31.7
SPEED 18.6
AGE GROUP 5
DWT GROUP 1

DISPLACEMENT 25656.3
BLOCK COEFF .705971
WATERPLANE COEFF .793498
PRISMATIC COEFF .720376
KM 30.3951
  ACTUAL VALUE 30.81
TPI 75.8074
  ACTUAL VALUE 75.9
MT1 2431.39
  ACTUAL VALUE 2351
LCB 266.93
  ACTUAL VALUE
LCF 275.592
  ACTUAL VALUE

DEADWEIGHT 33500
LENGTH 630
BEAM 84
DEPTH 47
DRAFT 36.5
SPEED 17.5
AGE GROUP 5
DWT GROUP 2

DISPLACEMENT 43626.6
BLOCK COEFF .790509
WATERPLANE COEFF .85428
PRISMATIC COEFF .797897
KM 34.0668
ACTUAL VALUE 34.6
TPI 107.639
ACTUAL VALUE 108
MT1 4466.08
ACTUAL VALUE 4417
LCB 305.782
ACTUAL VALUE 311.3
LCF 322.363
ACTUAL VALUE 326.8

DEADWEIGHT 41173
LENGTH 682
BEAM 93
DEPTH 48.5
DRAFT 36.2
SPEED 17.4
AGE GROUP 5
DWT GROUP 2

DISPLACEMENT 52941.9
BLOCK COEFF .807034
WATERPLANE COEFF .839195
PRISMATIC COEFF .81305
KM 36.1868
ACTUAL VALUE 38.15
TPI 126.73
ACTUAL VALUE 126.8
MT1 5572.36
ACTUAL VALUE 5760
LCB 329.212
ACTUAL VALUE
LCF 348.758
ACTUAL VALUE

DEADWEIGHT 52196
LENGTH 739.98
BEAM 89.99
DEPTH 56
DRAFT 42.81
SPEED 15.5
AGE GROUP 5
DWT GROUP 3

DISPLACEMENT 65564
BLOCK COEFF .804959
WATERPLANE COEFF .905196
PRISMATIC COEFF .811148
KM 38.6748
ACTUAL VALUE 37.1
TPI 143.518
ACTUAL VALUE 141.3
MT1 7455.09
ACTUAL VALUE 6820.0
LCB 357.447
ACTUAL VALUE 363.95
LCF 374.014
ACTUAL VALUE 380.35

DEADWEIGHT 60615
LENGTH 770
BEAM 104
DEPTH 60
DRAFT 41.75
SPEED 17.4
AGE GROUP 5
DWT GROUP 3

DISPLACEMENT 75373.9
BLOCK COEFF .789058
WATERPLANE COEFF .827679
PRISMATIC COEFF .796566
KM 40.5674
ACTUAL VALUE 42.7
TPI 157.811
ACTUAL VALUE 161.9
MT1 7701.54
ACTUAL VALUE 8485
LCB 373.913
ACTUAL VALUE
LCF 393.759
ACTUAL VALUE

DEADWEIGHT 267596
LENGTH 1043.3
BEAM 183.7
DRAFT 67.5
SPEED 15
AGE GROUP 2
DWT GROUP 5
DEPTH 86.6

DISPLACEMENT 305424
BLOCK COEFF .893909
WATERPLANE COEFF .839395
PRISMATIC COEFF .892715
KM 66.2024
ACTUAL VALUE 75.8
TPI 383.033
ACTUAL VALUE 412
MT1 25771.8
ACTUAL VALUE 30264
LCB 489.073
ACTUAL VALUE 495
LCF 525.693
ACTUAL VALUE 523

DEADWEIGHT 153294
LENGTH 879.27
BEAM 175.85
DRAFT 50.38
SPEED 15
AGE GROUP 2
DWT GROUP 4
DEPTH 65.62

DISPLACEMENT 178141
BLOCK COEFF .800403
WATERPLANE COEFF .79
PRISMATIC COEFF .80697
KM 66.7675
ACTUAL VALUE 75.2
TPI 293.00
ACTUAL VALUE 325
MT1 15652
ACTUAL VALUE 19684
LCB 425.373
ACTUAL VALUE 431
LCF 443.042
ACTUAL VALUE 440

DEADWEIGHT 86160
LENGTH 754.59
BEAM 137.8
DRAFT 41.77
SPEED 14.62
AGE GROUP 1
DWT GROUP 3
DEPTH 64.96

DISPLACEMENT 103968
BLOCK COEFF .837808
WATERPLANE COEFF .82015
PRISMATIC COEFF .84127

KM 51.873
ACTUAL VALUE NOT GIVEN
TPI 203.051
ACTUAL VALUE 206
MT1 9599.06
ACTUAL VALUE 10693
LCB 360.526
ACTUAL VALUE NOT GIVEN
LCF 379.323
ACTUAL VALUE NOT GIVEN

DEADWEIGHT 77453
LENGTH 748
BEAM 118.75
DRAFT 44
SPEED 15
AGE GROUP 2
DWT GROUP 3
DEPTH 59.875

DISPLACEMENT 94414
BLOCK COEFF .845506
WATERPLANE COEFF .926329
PRISMATIC COEFF .848329

KM 49.837
ACTUAL VALUE 48.48
TPI 195.908
ACTUAL VALUE 187.8
MT1 10530.1
ACTUAL VALUE 9643
LCB 356.454
ACTUAL VALUE 353
LCF 376.899
ACTUAL VALUE 375

DEADWEIGHT 234752
LENGTH 1092.5
BEAM 167.3
DRAFT 62.8
SPEED 15
AGE GROUP 1
DWT GROUP 5
DEPTH 85.89

DISPLACEMENT 290288
BLOCK COEFF .885157
WATERPLANE COEFF .863503
PRISMATIC COEFF .884689

KM 62.7013
ACTUAL VALUE 67.96
TPI 375.779
ACTUAL VALUE 388.0
MT1 27375.9
ACTUAL VALUE 29337
LCB 513.671
ACTUAL VALUE 521
LCF 550.483
ACTUAL VALUE 548

DEADWEIGHT 228499
LENGTH 1026.9
BEAM 167.3
DRAFT 65.4
SPEED 15
AGE GROUP 2
DWT GROUP 5
DEPTH 85.9

DISPLACEMENT 282637
BLOCK COEFF .88043
WATERPLANE COEFF .860162
PRISMATIC COEFF .880354

KM 62.7099
ACTUAL VALUE 68.6
TPI 351.848
ACTUAL VALUE 367.50
MT1 23986.3
ACTUAL VALUE 26221
LCB 483.606
ACTUAL VALUE 487
LCF 517.429
ACTUAL VALUE 514

DEADWEIGHT 66532
LENGTH 770.9
BEAM 104
DEPTH 60
DRAFT 44.6
SPEED 17.15
AGE GROUP 5
DWT GROUP 3

DISPLACEMENT 82151.4
BLOCK COEFF .804112
WATERPLANE COEFF .879333
PRISMATIC COEFF .810371
KM 42.8746 ACTUAL VALUE 42.9
TPI 167.856 ACTUAL VALUE 167.5
MT1 8806.54 ACTUAL VALUE
LCB 372.487 ACTUAL VALUE
LCF 393.617 ACTUAL VALUE

## APPENDIX B

Graphs Depicting Variance of Hydrostatic Properties with Changes in Trim

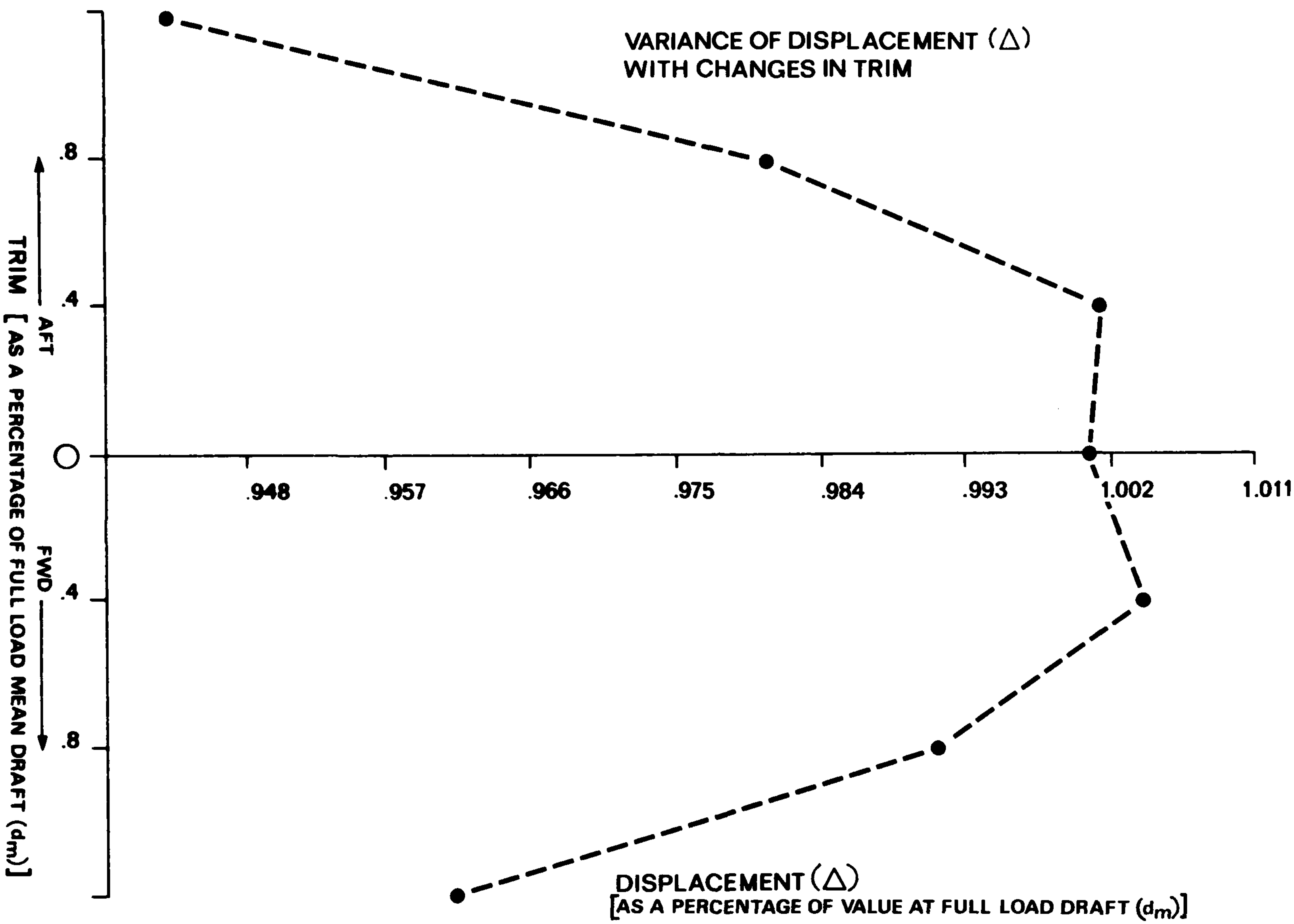

VARIANCE OF DISPLACEMENT (Δ)
WITH CHANGES IN TRIM
.948
.957
.966
.975
.984
.993
1.002
1.011
DISPLACEMENT (Δ)
[AS A PERCENTAGE OF VALUE AT FULL LOAD DRAFT ($d_m$)]
.8
.4
O
.4
.8
AFT
FWD
TRIM [AS A PERCENTAGE OF FULL LOAD MEAN DRAFT ($d_m$)]

Figure B-1

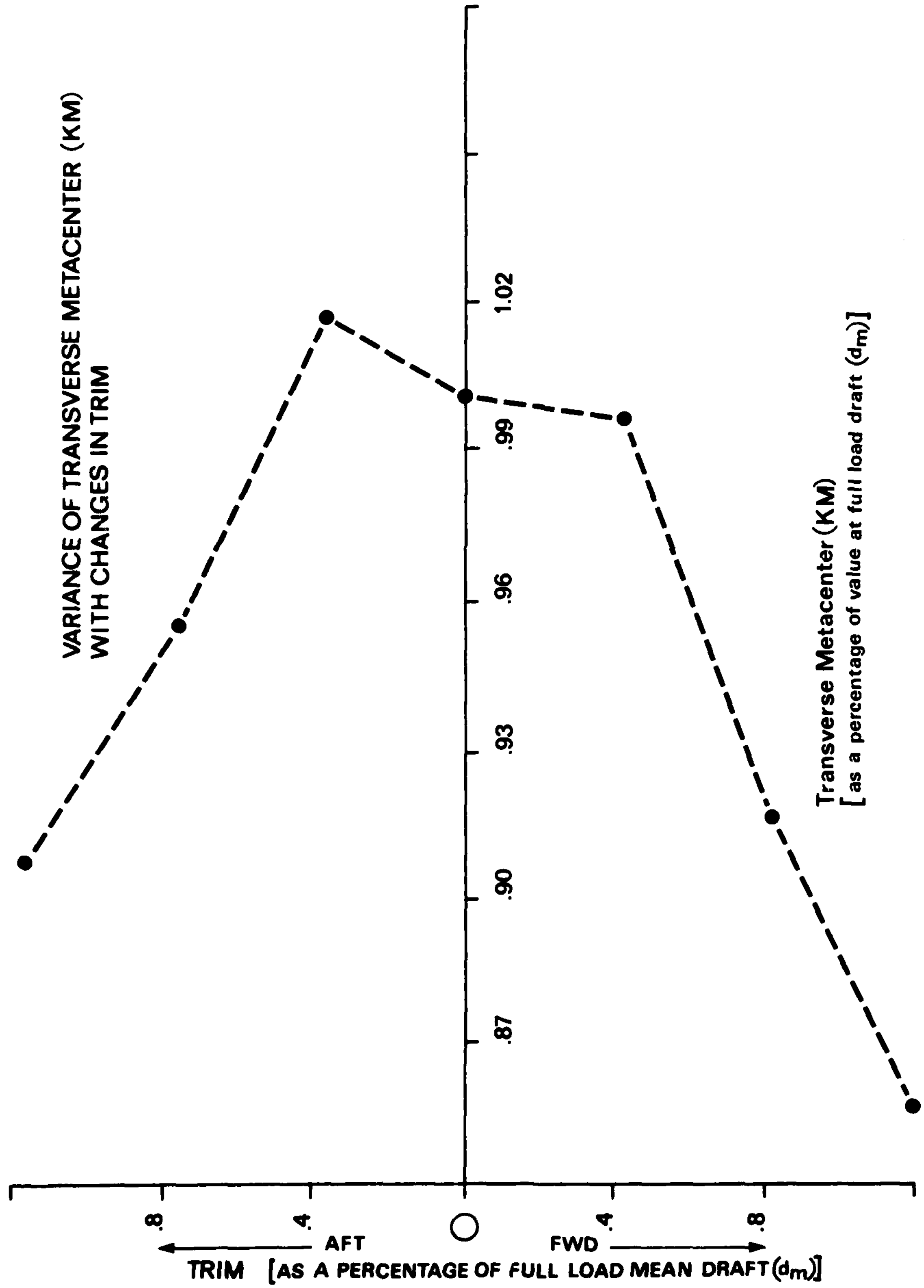

VARIANCE OF TRANSVERSE METACENTER (KM)
WITH CHANGES IN TRIM
Transverse Metacenter (KM)
[as a percentage of value at full load draft ($d_m$)]
1.02
.99
.96
.93
.90
.87
.8
.4
O
.4
.8
AFT
FWD
TRIM [AS A PERCENTAGE OF FULL LOAD MEAN DRAFT ($d_m$)]

Figure B-2

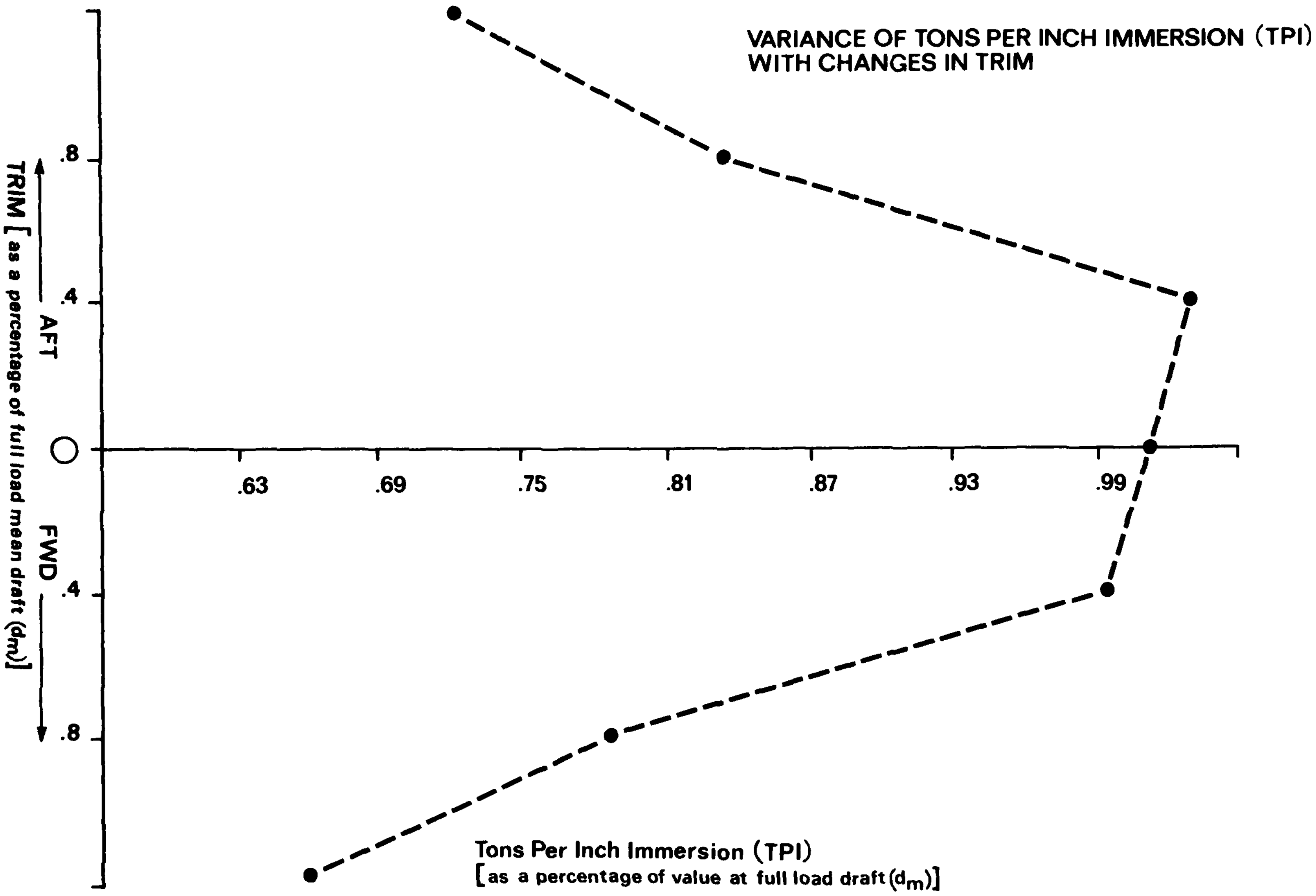

VARIANCE OF TONS PER INCH IMMERSION (TPI)
WITH CHANGES IN TRIM
.63
.69
.75
.81
.87
.93
.99
Tons Per Inch Immersion (TPI)
[as a percentage of value at full load draft ($d_m$)]
.8
.4
O
.4
.8
AFT
FWD
TRIM [as a percentage of full load mean draft ($d_m$)]

Figure B-3

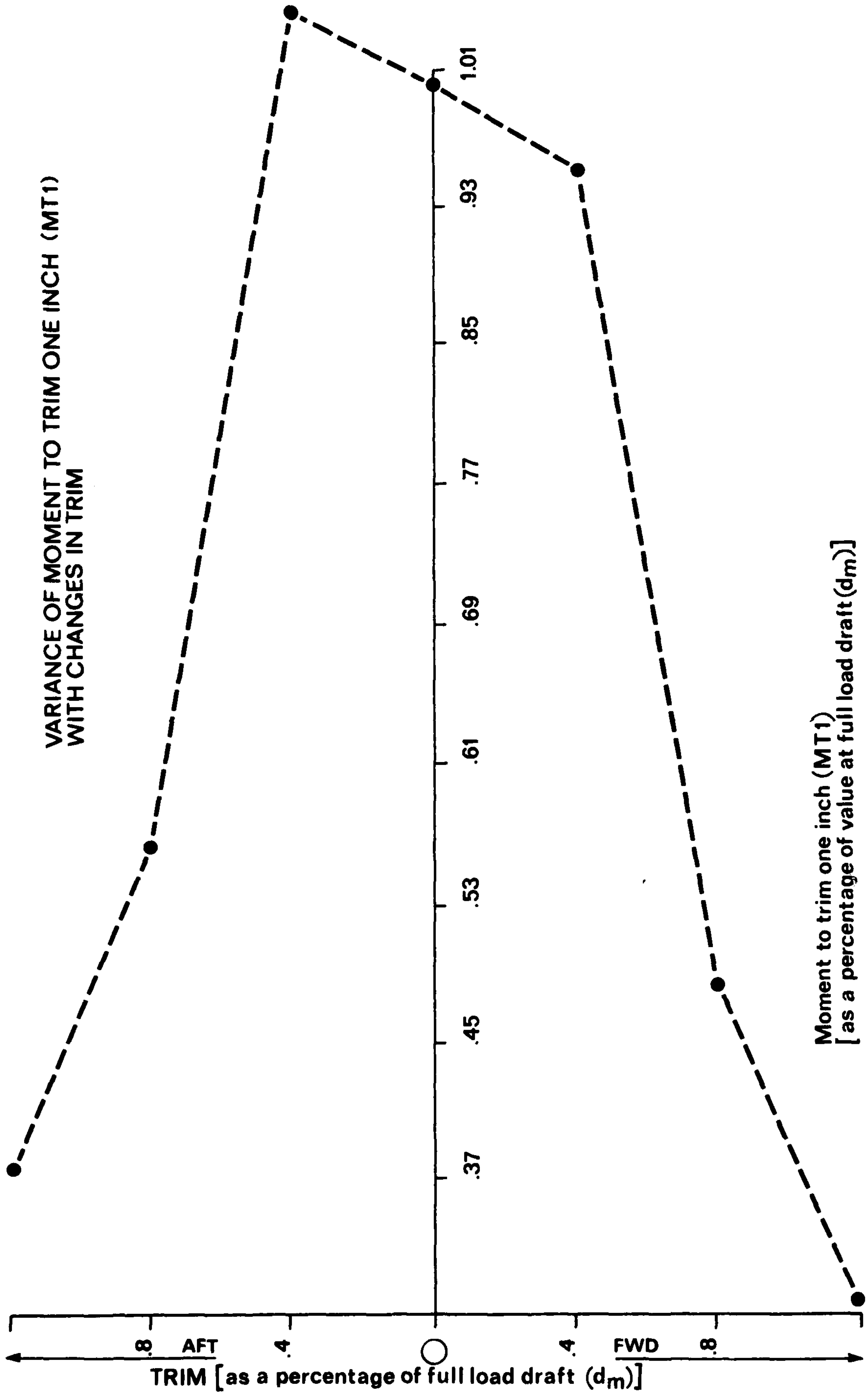

VARIANCE OF MOMENT TO TRIM ONE INCH (MT1)
WITH CHANGES IN TRIM
1.01
.93
.85
.77
.69
.61
.53
.45
.37
Moment to trim one inch (MT1)
[as a percentage of value at full load draft ($d_m$)]
8
AFT
4
0
4
FWD
8
TRIM [as a percentage of full load draft ($d_m$)]

Figure B-4

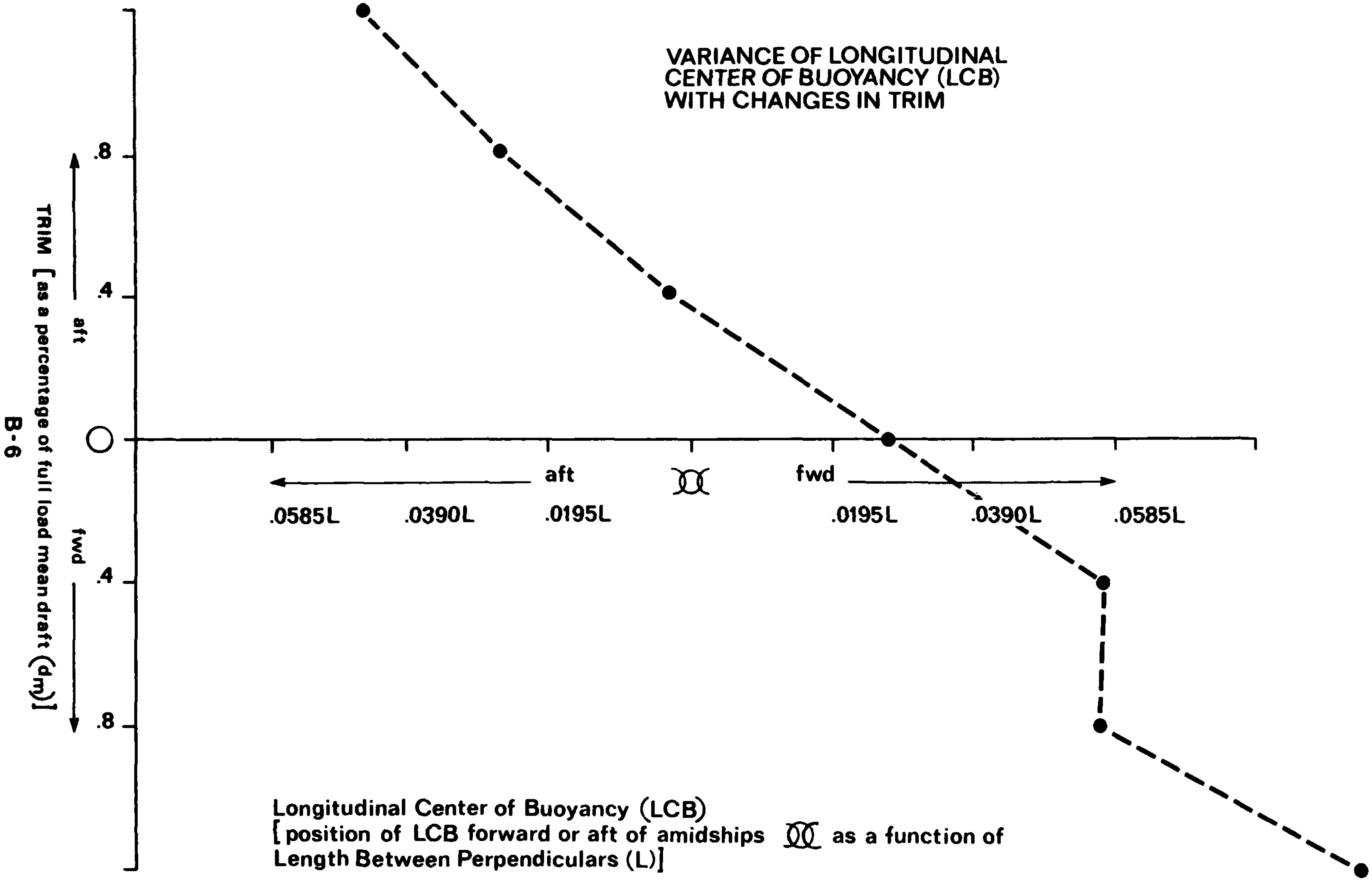
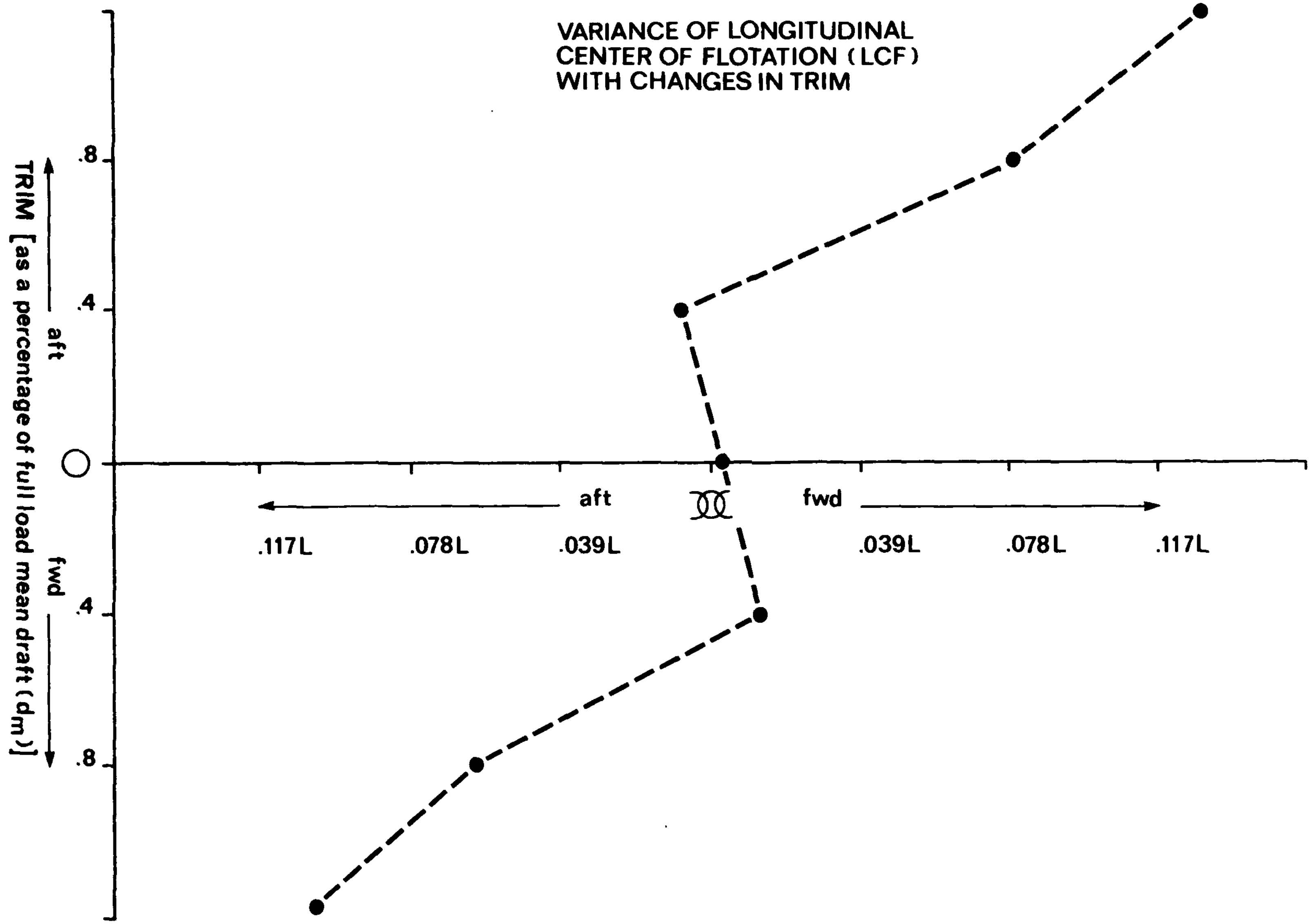

VARIANCE OF LONGITUDINAL
CENTER OF BUOYANCY (LCB)
WITH CHANGES IN TRIM
.8
.4
0
.4
.8
aft
fwd
TRIM [as a percentage of full load mean draft ($d_m$)]
aft
fwd
.0585L
.0390L
.0195L
.0195L
.0390L
.0585L
Longitudinal Center of Buoyancy (LCB)
[position of LCB forward or aft of amidships as a function of
Length Between Perpendiculars (L)]

Figure B-5




Longitudinal Center of Flotation (LCF)
[position of LCF forward or aft of amidships as a function of Length Between Perpendiculars (L)]

Figure B-6

# BIBLIOGRAPHY

Beakley, George and Leach, H.W. Engineering: An Introduction to a Creative Profession. New York, N.Y.: Macmillan and Co., 1972.

Porricelli, Joseph; Boyd, J. Huntley; and Schleiffer, Keith. Modern Analytical Techniques in Salvage Engineering Using Portable Computers, New York, N.Y.: Society of Naval Architects and Marine Engineers, 9 November 1983.

American Bureau of Shipping. Rules for Building and Classing Steel Vessels, New York, N.Y.: 1982

H. Clarkson and Company, Limited. The Tanker Register. London, England: 1982

Porricelli, Joseph D., and Boyd, J. Huntley, Jr. Analytical Techniques for Predicting Grounded Ship Responses. Washington, D.C.: Ship Structure Committee, 1983, SR 1294.

END

FILMED

4-85

DTIC